Regimes of Growth and Economic Integration

Why Poor Countries Cannot Join the "Club" of the Rich?

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The author argues that different regimes of growth experienced by rich and poor economies create barriers to global economic integration through the world capital market. The lack of capital flows from rich to poor countries is explained by the heterogeneity of these countries in terms of the engine of growth. The pattern of integration is determined for an open economy by its initial ratio of knowledge to assets: if it is high, the economy is booming, otherwise it grows gradually. This is an implication of the comparative advantage principle: a capital-scarce country attracts new investment at the initial stage of integration, while a capital-redundant country exports capital at this stage.

Keywords. Russia, economic growth, integration, international capital market, club convergence.

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CONTENTS

NON-TECHNICAL SUMMARY

The paper aims to explain obstacles to economic integration of advanced and backward economies by analyzing qualitatively different regimes of growth experienced by developed and less developed economies. By qualitative difference of growth we mean that there are well-developed sectors of the economy serving as engines of growth in some countries while they are suppressed or absent in others. Obstacles to economic integration of backward countries with the industrial world are viewed here as substantially endogenous, and the lack of capital flows from rich to poor economies is explained by their heterogeneity in terms of the engine of growth.

We utilize a modified two-sector model of endogenous growth with an intermediate knowledge accumulation sector (the Lucas–Uzawa framework). This class of models permits the existence of interior and corner solutions. An interior solution is an equilibrium path with positive time devoted to knowledge creation and *endogenous* economic growth. Growth along the corner path is *exogenous* in the sense that it is not led by individual efforts to produce knowledge.

We show that international interest rate equalization results in a close cross-country interdependence of household behavior in terms of time allocation. Integration of countries through international capital markets requires that the worldwide endogenous growth rate is positive and none of the participating countries run exponential non-collateralized debt. According to the first condition, marginal productivity of knowledge creation is quite high in all countries, and, as to the second condition, it does not vary much across countries. These provisions are quite restrictive for realistic parameter values and are only fulfilled if less advanced economies do not participate in the world capital market, even if some of them are able to grow endogenously in autarky. A possible interpretation of this conclusion is that heterogeneity of countries in terms of the growth engine rather than production technology and household preferences constitutes a crucial barrier to economic integration.

In the absence of international knowledge spillovers, an exogenously growing economy can integrate with the global capital market in a very specific pattern if it becomes a *rentier* economy. In this case all national assets are invested abroad, all initial production capital evaporates from the country, and human capital is not utilized in production. Welfare analysis demonstrates that trade in the capital market may force some

economies to become rentiers even if they are able to grow endogenously in autarky. This occurs if the discount rate is quite low, thereby indicating no positive connection between "thriftiness" and growth for the open economy.

Integration opportunities of less advanced countries with the global economy substantially widen due to positive knowledge spillovers. We introduce spillover effects embodied through foreign investment in production capital for a small economy open to the world capital market. Our conclusions are that foreign investment can mitigate but not remove barriers to integration faced by a backward economy. Due to the spillovers it can grow endogenously even if its ability to produce knowledge is insufficient for endogenous growth in autarky. It can also grow exogenously without transforming to the rentier type.

We also show that there may be two patterns of transition growth in each regime. The first pattern is characterized by a high initial capital inflow into the country and sluggish capital growth along the transition path. Production capital increases initially after opening the economy, but in transition to the steady state it grows slower than the world economy and domestic consumption. We call such a pattern of development *booming* because the opening of domestic capital markets implies an immediate and sharp inflow of capital into the country. Under the second, *gradual* growth pattern, capital initially outflows from the country but in transition accumulates at a faster pace than domestic consumption.

The choice of the growth pattern is determined by the initial ratio of knowledge to assets: if it is above a threshold level, the economy is booming; otherwise, it grows gradually. This is an implication of the comparative advantage principle to a dynamic economy: a capital-scarce country attracts new investment at the initial stage of integration while a capital-redundant country exports capital at this stage. This conclusion is consistent with the empirical findings suggesting that foreign direct investment has a significantly positive impact on economic growth in the host country only if it has a stock of human capital above a threshold level.

1. INTRODUCTION

The paper discusses several stylized facts of global economic growth. First, growth rates converge among industrial countries but diverge for the whole world. Second, an overwhelming share of foreign investment flows between developed countries, whereas less developed nations face obstacles to integrate with the industrial world. Third, patterns of integration are different across countries, *i.e.*, some of them experience rapid growth of production investment and output while others suffer outflow of capital and only gradually are able to increase domestic stock of production assets. Fourth, growth in developing and transition economies is uneven over time.[1]

We try to explain these phenomena by analyzing qualitatively different regimes of growth experienced by developed and less developed economies. By qualitative difference of growth we mean that there are well-developed sectors of the economy serving as engines of growth in some countries while they are suppressed or absent in others. Many endogenous growth models generating sustained growth per capita predict absolute divergence of growth rates between rich and poor economies due to cross-country differences in technology, factor endowments, preferences, policy, etc. Most of them consider the closed economy case and abstract from interconnections between international trade and growth. Models of trade and growth (for instance by Segerstrom *et al*., 1990; Young, 1991; Grossman and Helpman, 1991) have studied various effects of trade impediments on growth differentials but have received ambiguous conclusions.

The main question raised in this paper is in a sense opposite to the aforementioned: can different regimes of growth experienced by rich and poor economies create barriers to global economic integration through the world capital market? Obstacles to economic integration of backward countries with the industrial world are viewed here as substantially endogenous, and the lack of capital flows from rich to poor economies is explained by their heterogeneity in terms of the engine of growth. To simplify this analysis we abstract from essentially exogenous factors constraining international capital flows like

[1] See, for instance, Pritchett (1997), Durlauf and Quah (1999) and Easterly and Levine (2001).

political risks and monopoly control over trade emphasized, for instance, by Lucas (1990).

We utilize a modified two-sector model of endogenous growth with an intermediate knowledge accumulation sector proposed originally by Lucas (1988) and Uzawa (1965). This class of models permits the existence of interior and corner solutions. An interior solution is an equilibrium path with positive time devoted to knowledge creation and *endogenous* economic growth. Growth along the corner path is *exogenous* in the sense that it is not led by individual efforts to produce knowledge. Existence of endogenous and exogenous growth paths in the Lucas–Uzawa framework has been demonstrated by Rebelo (1991), Caballe and Santos (1993), Goodfriend and McDermott (1995), and Ladron-de-Guevara *et al*. (1999).

A modification of the Lucas endogenous growth model we focus on assumes that leisure enters into household utility. It was suggested by Rebelo (1991), and Jones *et al*. (1993), then developed by Benhabib and Perli (1994), Ortiguera and Santos (1997), Ladron-de-Guevara *et al*. (1999). The crucial feature of this model is that the level of human capital does not change the marginal utility of leisure and has an unequal influence on the efficiency of time spent in different activities. By entering leisure into the model this way, Rebelo (1991) and Jones *et al*. (1993) focus on the issues of long-term effects of taxation on growth, and Benhabib and Perli (1994) consider indeterminacy of solutions for a wide range of plausible model parameters. Ladron-de-Guevara *et al*. (1999) demonstrate the existence of equilibrium path and reveal three balanced growth paths such that two are interior and one is a corner solution. Their comparative analysis focuses merely on the interior solutions.

Unlike Ladron-de-Guevara *et al*. (1999), we place emphasis on the comparison of two qualitatively different regimes of growth: endogenous and exogenous, corresponding to the interior and corner solution. This is essential for drawing conditions of endogenous growth and economic integration. Although our paper uses a simple version of earlier endogenous growth models with leisure in utility, it makes a contribution in two respects. On one hand, it contains an explicit analysis of the exogenous growth path, a welfare comparison of the growth regimes and develops a local analysis of transition dynamics in autarky. As shown below, an economy cannot grow endogenously if the marginal productivity of knowledge creation is low, the discount rate is high, or the elasticity of leisure is high. Besides that, high impatience and propensity toward leisure make exogenous growth regime in autarky welfare-preferable for households. The inability or unwillingness of a poor country to generate endogenous growth explains its economic backwardness.[2]

On the other hand, the autarky model is extended to the global economy where national economies differ in marginal productivities of knowledge creation, capital is a mobile factor of production, and labor is an immobile factor. This extension is similar to the global economy model with free capital movement as outlined by Lucas (1993) where countries differ only in initial conditions. It is also comparable to the dynamic models of the global economy with factor price equalization through trade in goods as proposed by Stokey (1996) and Ventura (1997), Acemoglu and Ventura (2002).

We show that international interest rate equalization results in a close cross-country interdependence of household behavior in terms of time allocation (explaining, in our view, certain standardization of household behavior across countries closely linked economically). Leisure preference proves to be an important property of the global economy model of growth stipulating realistic transition dynamics with a finite speed of convergence to the steady state. If households are indifferent to leisure, as in the basic Lucas (1988) model, then interest rate equalization implies a counterfactual outcome when all capital and production concentrates instantaneously in the most advanced country.

Integration of countries through international capital markets requires that the worldwide endogenous growth rate is positive and none of the participating countries run exponential non-collateralized debt. According to the first condition, marginal productivity of knowledge creation is quite high in all countries, and, as to the second condition, it does not vary much across countries. These provisions are quite restrictive for realistic parameter values and are only fulfilled if less advanced economies do not participate in the world capital market. Notably, some of these economies are able to grow endogenously in autarky. A possible interpretation of this conclusion is that heterogeneity of countries in terms of the growth engine rather than production technology and household preferences constitutes a crucial barrier to economic integration.

[2] These findings are similar to conclusions of the underdevelopment trap theory. Unlike models of that theory we do not assume externalities implying multiple Pareto-ranked equilibria as, *e.g.*, Murphy *et al*. (1989), Azariadis and Drazen (1990), and Krugman (1991). In the model of our paper, the inability of poor countries to achieve the regime of sustained long-run growth is linked with structural constraints on parameters rather than initial endowments or beliefs, as in the aforementioned papers. The slow-growth equilibrium path in our paper is not necessary Pareto-inferior to the fast-growth path.

Economies with less advanced growth-generating sectors are unable to join "the club" of industrial nations since they are unable to adjust to global economy dynamics in terms of leisure and capital position. In a sense, if the global economy is "too" heterogeneous, it cannot "find" an equilibrium trajectory approaching the endogenous balanced growth path.[3]

In the absence of international knowledge spillovers, an exogenously growing economy can integrate with the global capital market in a very specific pattern if it becomes a *rentier* economy. In this case all national assets are invested abroad, all initial production capital evaporates from the country, and human capital is not utilized in production. The ratio of household assets to production capital is infinity, households devote all time to leisure, and their per capita assets grow at the worldwide rate. As we show, such a steady state is reached in finite time.

Welfare analysis demonstrates that trade in the capital market may enforce some economies to become rentiers even if they are able to grow endogenously in autarky. This occurs if the discount rate is quite low. There is no positive connection between "thriftiness" and growth for the open economy, and excessively thrifty households would prefer financial investment to creative activities. This model prediction is in sharp contrast with J. Ventura's (1997, p. 76) conclusion that the secret of growth miracles is to "open the economy and be patient".

Integration opportunities of less advanced countries with the global economy substantially widen due to knowledge spillovers. We introduce spillover effects embodied through foreign investment in production capital for a small economy open to the world capital market. This is essentially close to the assumptions about spillover effects of direct foreign investment suggested earlier by Findlay (1978) and Wang (1990). These authors did not use dynamic optimization and applied models of growth with exogenous technical progress. They demonstrated that knowledge-transferring foreign investment remove a growth gap between advanced and backward economies. Our conclusions are similar though somewhat ambiguous: foreign investment can mitigate but not remove barriers to integration faced by a backward economy. Due to the spillovers it can grow endogenously even if its ability to produce knowledge is insufficient

[3] The possibility of "club convergence" was demonstrated earlier by P. Howitt (2000) for a model of global productivity growth with cross-country technology transfers. This property is a consequence of the Kuhn-Tucker generalization of research arbitrage equation (Howitt, 2000, p. 837) forbidding negative intensity of research. However, club convergence in the Howitt model does not necessarily stem from the structural diversity of the world economy.

for endogenous growth in autarky. It can also grow exogenously without transforming to the rentier type.

We also show that there may be two patterns of transition growth in each regime. The first pattern is characterized by a high initial capital inflow into the country and sluggish capital growth along the transition path. Production capital increases initially after opening the economy, but in transition to the steady state it grows slower than the world economy and domestic consumption. We call such a pattern of development *booming* because the opening of domestic capital markets implies an immediate and sharp inflow of capital into the country. Under the second, *gradual* growth pattern capital initially outflows from the country but in transition accumulates at a faster pace than domestic consumption.

The choice of the growth pattern is determined by the initial ratio of knowledge to household assets: if it is above a threshold level, the economy is booming; otherwise, it grows gradually. This is an implication of the comparative advantage principle to a dynamic economy: a capital-scarce country attracts new investment at the initial stage of integration while a capital-redundant country exports capital at this stage. This conclusion is consistent with the empirical findings suggesting that foreign direct investment have a significantly positive impact on economic growth in the host country only if it has a stock of human capital above a threshold level, *e.g.*, in Borensztein *et al*. (1998).

We demonstrate that in both regimes of growth, the gradual pattern of transition welfare-dominates the booming pattern if households are leisure-loving. A policy conclusion from the analysis of growth patterns is that reliance on foreign investment as a sole engine of rapid economic growth is probably a misleading strategy for backward economies. If the country does not try to develop domestic knowledge production, it may become unattractive for foreign investment at initial stages of integration.

The rest of the paper consists of three sections and a conclusion. Section 1 examines the closed economy model, section 2 extends it to the global economy, and section 3 focuses on knowledge spillovers and transition patterns. Proofs of propositions are collected in the Appendices.

2. THE MODEL OF AN AUTARKY ECONOMY

The economy is populated with representative agents endowed with two production factors, physical capital and labor. These agents make consumption-investment decisions that maximize discounted utility on an in-finite time horizon. The number of workers equals the number of population growing at a constant rate v.

The individual decision problem is

$$\max_{c,l,e,u,k,h} \int_0^\infty e^{-(\rho-v)t}(\ln c + \theta \ln l)dt \,, \tag{2.1}$$

$$\dot{k} = y - (d+v)k - c \,, \tag{2.2}$$

$$\dot{h}/h = g_0 + g_1 e \,, \tag{2.3}$$

$$u + e + l = 1 \,, \tag{2.4}$$

$$e \geq 0 \,. \tag{2.5}$$

Instantaneous utility is a log-additive function of consumption c and leisure l. Individual preferences are described with elasticity of leisure θ, and individual discount rate ρ, $\rho > v$. The net discount rate is $\delta = \rho - v$. Production technology is Cobb–Douglas with Harrod-neutral technical progress: $y = k^{\alpha}(uh)^{1-\alpha}$, where y is output, k is physical capital, h is the number of efficiency units or human capital (knowledge) of the worker, α is the share of capital in output, and u is the intensity of labor inputs in production. Human capital is regarded here as a measure of technical knowledge and experience indicating the level of technology rather than average years of schooling. All variables in the production function are expressed in per-capita terms.

Equation (2.2) is the budget constraint, and (2.3) relates to human capital accumulation. Physical and human capital depreciates at rate d and $-g_0$, respectively. Positive g_0 measures the rate of autonomous technical progress independent from individual intensity of knowledge creation e. The term $g_1 eh$ in (2.3) is interpreted from the Lucas model (1988) as a homogenous production function with human capital as a sole factor of knowledge accumulation. Parameter $g_1 > 0$ measures marginal productivity of knowledge creation. Equation (2.4) is a balance of time divided between leisure, production and research. Constraint (2.5) restricts effort to produce knowledge from being negative. Production effort and leisure are always positive in equilibrium, and we ignore the corresponding constraints. Depending on whether (2.5) is binding or not in equilibrium, we consider two regimes of economic dynamic, exogenous and endogenous.

2.1. Endogenous growth

Equilibrium dynamic in the endogenous growth regime is represented by three key ratios: consumption rate $x = c/k$, (gross) interest rate $r = \partial y/\partial k$, and leisure l.

Proposition 1. The endogenous growth trajectory satisfies the system

$$\dot{x}/x = x - \beta r - \delta, \tag{2.6}$$

$$\dot{r}/r = \beta(d + \nu + g_0 + g_1(1 - l) - r), \tag{2.7}$$

$$\dot{l}/l = g_1 u - \delta, \tag{2.8}$$

where

$$\beta = (1 - \alpha)/\alpha, \quad \text{and} \quad u = \beta r\, l/\theta x.^4 \tag{2.9}$$

We study in what follows transitional equilibrium dynamics, and now characterize an endogenous balanced growth path. Output, consumption, and both types of capital are growing exponentially along this path with the same constant rate of growth while proportions of time allocation are held constant. The steady state equations for (2.4), (2.6)–(2.9) are[5]

$$x = \beta r + \delta, \tag{2.10}$$

$$r = d + \rho + g_0 + g_1 e, \tag{2.11}$$

$$u = \delta/g_1, \tag{2.12}$$

$$e = 1 - (1 + \theta + \delta\theta/\beta r)\delta/g_1, \tag{2.13}$$

$$l = \theta(1 + \delta/\beta r)\delta/g_1. \tag{2.14}$$

Equation (2.10) determines steady-state consumption as a share of household wealth. The interest rate, equation (2.11), is the sum of the depreciation rate, discount rate and GDP growth rate. Equations (2.12)–(2.14) determine the steady-state allocation of time. Note for future reference that the long run consumption rate can be represented as a function of time fractions:

$$x = \delta l/(l - \theta u). \tag{2.15}$$

Combining (2.11) and (2.13) yields a steady-state interest rate equation:

$$r^2 - (R - \delta\theta)r + \delta^2\theta/\beta = 0, \tag{2.16}$$

[4] Equation (2.9) can be interpreted as a consumption-wage relationship if one represents it as $x/\beta r = l/\theta\, u$. The term $x/\beta r$ characterizes the proportion between consumption and wage since $\beta r = (1 - \alpha)y/k$. In equilibrium this proportion is equal to the ratio of leisure to working time weighted by the elasticity of leisure θ.

[5] We rule out steady states with zero x or r since corresponding trajectories do not constitute balanced growth paths and are dynamically inefficient.

where $R = d + \nu + g_0 + g_1$.

Let r_1 denote the minimal root and r_2 the maximal root of (2.16). Both roots are real and positive if $R - \delta\theta > 2\delta(\theta/\beta)^{1/2}$. Therefore, system (2.6)–(2.9) has two stationary states assuming either the parameters of knowledge production g_0 and g_1 are high or the elasticity of leisure θ is low.

A positive interdependence between the interest rate and the endogenous growth rate, equations (2.11) and (2.13), imply a multiplicity of steady state solutions. The steady state interest rates r_1 and r_2 are substantially different for empirically relevant parameter values. Ladron-de-Guevara *et al*. (1999) emphasize qualitative differences between internal paths corresponding to these roots. However, the lower root of (2.16) is in many cases an implausible solution because the intensity of knowledge creation must be positive. For the steady state this implies that

$$g_1 > \delta(1 + \theta + \delta\theta/\beta r^{(e)}). \tag{2.17}$$

Here and in what follows superscript (e) relates to endogenous stationary growth. If, for instance, δ is sufficiently small, then (2.17) is fulfilled for r_2, but not for r_1. The case when the discount rate is low is important from theoretical and empirical points of view, and just in this case the lower internal solution has to be ruled out.[6]

The steady state growth rate is obtained from (2.3) and (2.13):

$$g^{(e)} = (g_0 + g_1) - (1 + \theta)\delta - \theta\delta^2/\beta r^{(e)}. \tag{2.18}$$

The higher the discount rate or the elasticity of leisure the lower the endogenous growth rate. This fits the intuition since long-term growth is lower when individuals are impatient or place high value on leisure. The third term on the right hand side of (2.18) reflects the positive link between the interest rate and endogenous growth.

Consider a numerical example; this will serve as reference for our later study, by setting the following parameter values: $g_0 = 0$, $\nu = 0$, $\delta = 0.025$, $\beta = 1.5$, and $d = 0.03$. Table 1 contains steady state estimates for this set of parameters along with different values of θ and g_1. These two parameters are selected so that the interest rate is

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[6] We do not rule it out a priori but keep in mind that it is most likely an economically irrelevant solution for reasonable parameter values. As computations in Ladron-de-Guevara *et al*. (1999, p. 619–620) demonstrate, (2.17) holds for r_1 for quite a narrow domain of the model parameters (for the log utility), and the steady state corresponding to r_1 is not optimal for the model with no adjustment costs. In many cases this state is unstable.

nearly the same for all variants of calculation. The lower root of (2.16), r_1, does not satisfy (2.17), therefore, $r^{(e)} = r_2 = 0.085$. Consumption rate and endogenous growth rate are also nearly the same for all variants with $x^{(e)} = 0.153$ and $g^{(e)} = 0.03$. The corresponding consumption-output ratio is equal to $x^{(e)}\alpha/r^{(e)} = 0.72$. The share of time spent on knowledge creation varies between 0.23 and 0.3 for the empirically relevant interval of leisure elasticity [1.5, 2.5]. The fraction of leisure is between 0.45 and 0.58.

Table 1.

θ	0.5	1.0	1.5	2.0	2.5
g_1	0.070	0.085	0.100	0.115	0.130
r_1	0.002	0.005	0.007	0.010	0.012
r_2	0.085	0.085	0.085	0.085	0.085
$l^{(e)}$	0.213	0.352	0.448	0.520	0.575
$u^{(e)}$	0.357	0.294	0.250	0.217	0.192
$e^{(e)}$	0.430	0.354	0.302	0.263	0.233

If households are indifferent to leisure, $\theta = 0$, the model becomes a special case of the Lucas (1988) model with no external effects of knowledge creation and logarithmic utility. There is no positive feedback between the long-run interest rate and endogenous growth, and the steady state solution is found directly. The long run growth rate, in this case, is $g^{(e)}= g_0 + g_1 - \delta$,[7] whereas the long run interest rate is $r^{(e)} = R$. Time allocation is: $u^{(e)} = \delta/g_1$, $e^{(e)} = 1- \delta/g_1$, and $l^{(e)} = 0$. The fraction of time devoted to knowledge production is too high, as predicted by the Lucas model. For the above numerical example, $e^{(e)}$ varies between 0.643 and 0.808 ($g^{(e)}$ takes values between 0.045 and 0.105, that are also excessive).[8]

[7] As implied from (2.18) and the growth rate equations (24) and (26) in the Lucas paper.

[8] Using isoelastic utility is not a remedy. This disadvantage of the Lucas model underlies a criticism of the human capital theory of growth by S. Parente and E. Prescott (2000, p. 57–62).

2.2. Exogenous growth

We define an exogenous growth regime as a corner solution to the consumer problem (2.1)–(2.5), such that the intensity of knowledge creation is zero along the whole equilibrium path. In this case, the equilibrium dynamic is defined by variables x and r. Time fractions u and l are determined as functions of these variables.

Proposition 2. Equilibrium exogenous growth trajectory satisfies the system

$$\dot{x} / x = x - \beta r - \delta, \tag{2.19}$$

$$\dot{r} / r = \beta \frac{a + \rho + g_0 + u\dot{x} / x - r}{1 + \beta u}. \tag{2.20}$$

Production intensity and leisure are

$$u = \frac{\beta r}{\beta r + \theta x}, \; l = \frac{\theta x}{\beta r + \theta x}. \tag{2.21}$$

The balanced growth path in the exogenous growth regime is a steady state of (2.19)–(2.20), ($x^{(x)}$, $r^{(x)}$) found directly:

$$x^{(x)} = \beta r^{(x)} + \delta, \tag{2.22}$$

$$r^{(x)} = d + \rho + g_0 \tag{2.23}$$

(superscript (x) relates to the exogenous steady state growth). The per capita growth rate is $g^{(x)} = g_0$. The steady-state consumption rate can be represented as a function of time fractions identical to (2.15). The relationship between time devoted to work and leisure is different for the endogenous and exogenous balanced growth paths. If, for instance, the discount rate is near zero, the fraction of leisure tends to approach 0 in the former case (for $r^{(e)} = r_2$), and $\theta/(1 + \theta)$ in the latter case.

For the above numerical example and when $\theta = 2$, $g_1 = 0.1$, we have: $r^{(x)} = 0.055$, $u^{(x)} = 0.277$, $l^{(x)} = 0.723$. Consumption rate is $x^{(x)} = 0.108$, and the ratio of consumption to output is 0.78. In our view, this and the above numerical examples demonstrate the empirical relevance of the model for the stationary growth regimes.

2.3. Welfare comparison of regimes

Individuals may prefer exogenous growth even if endogenous growth is feasible. If utility gain from leisure outweighs utility loss from consumption growth, exogenous growth is welfare preferable. We cannot calculate integral utility for the transition growth paths and, instead, compare welfare for the steady state paths. Each of them is defined by the initial ratio of factor endowments h_0/k_0, as the next subsection demonstrates. For the sake of convenience (and without loss of generality) we assume here that initial capital stocks are identical for both steady state paths, and the ratios h_0/k_0 may vary between them only when the initial knowledge stocks are different. The difference in welfare between these paths is defined by a growth and level effect. The endogenous growth rate is $g_1e^{(e)}$ and the integral utility gain from higher consumption growth is

$$\int_0^\infty e^{-\delta t}\ln e^{g_1 e^{(e)}t}dt = g_1e^{(e)}\int_0^\infty e^{-\delta t}tdt = \delta^{-2}g_1e^{(e)}.$$

The integral level effect is

$$\int_0^\infty e^{-\delta t}\ln\frac{c^{(e)}}{c^{(x)}}\left(\frac{l^{(e)}}{l^{(x)}}\right)^\theta dt = \ln\frac{x^{(e)}}{x^{(x)}}\left(\frac{l^{(e)}}{l^{(x)}}\right)^\theta\int_0^\infty e^{-\delta t}dt = \delta^{-1}\ln\frac{x^{(e)}}{x^{(x)}}\left(\frac{l^{(e)}}{l^{(x)}}\right)^\theta.$$

Endogenous growth is preferable, if and only if the growth effect dominates the level effect:

$$g_1e^{(e)} \geq \delta \ln\,(x^{(x)}/x^{(e)})(l^{(x)}/l^{\,(e)})^\theta. \tag{2.24}$$

If the discount rate is low, the right hand side of (2.24) is positive and small. Although the level effect favors the choice of exogenous growth for low δ, since $l^{(x)}/l^{(e)}$ is high, the growth effect dominates. Highly patient households would prefer endogenous growth. This is not the case for the open economy as we shall see in what follows.

2.4. Transitional dynamics

Individuals under an endogenous growth regime select initial consumption rate x_0 and leisure l_0 when facing an initial interest rate r_0 satisfying the equilibrium conditions. This choice is predetermined by initial knowledge-capital ratio h_0/k_0. The equilibrium interest rate and production intensity solve equations (2.9) and $r = \partial y/\partial k$, implying that

$$x = (\beta/\theta)\ (h/k)r\psi(r)l, \tag{2.25}$$

where

$$\psi(r) \equiv (r/\alpha)^{-1/(1-\alpha)} = k/uh$$

is the input structure of production. Initial ratio $h/k = h_0/k_0$ in (2.25) defines a surface of initial values in (x, r, l) space.

Given h_0/k_0, the exogenous growth path is defined by x_0 and r_0. Capital allocation condition $r = \partial y/\partial k$ and (2.21) imply

$$x = (\beta/\theta)r[(h/k)\psi(r) - 1], \tag{2.26}$$

and h_0/k_0 determines a curve of initial values in (x, r) space.

Proposition 3. The endogenous growth trajectory converging to $(x^{(e)}, r^{(e)}, l^{(e)})$ is a saddle if and only if

$$\delta/r^{(e)} < (\beta/\theta)^{1/2}. \tag{2.27}$$

The exogenous growth trajectory converging to $(x^{(x)}, r^{(x)})$ is a saddle.

Condition (2.27) is fulfilled for $r^{(e)} = r_2$. Otherwise $R - \delta\theta < 2\delta\,(\theta/\beta)^{1/2}$ (because $r^{(e)} > (R - \delta\theta)/2$) and equilibrium equation (2.16) does not have real roots. Consequently a unique equilibrium path exists for the maximal root of (2.16).

Proposition 3 is illustrated in Figs 1 and 2. Fig. 1 portrays the phase space (x, r, l) and equilibrium endogenous growth trajectory. It starts from initial point $O = (x_0, r_0, l_0)$ belonging to the locus of initial values M, and converges to steady state $G = (x^{(e)}, r^{(e)}, l^{(e)})$. Fig. 2 shows the locus of initial values M and the equilibrium trajectory for the exogenous growth case. Both x and r are decreasing during the transition for the depicted case since h_0/k_0 is quite high and M is quite far from the origin.[9]

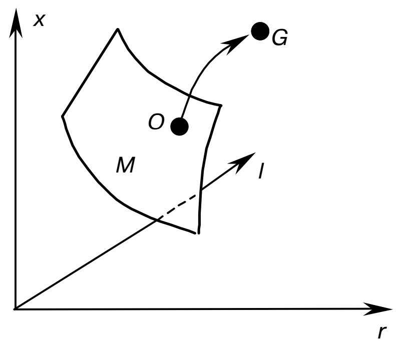

Fig. 1. Endogenous growth path.

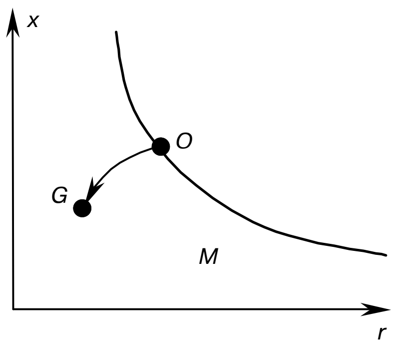

Fig. 2. Exogenous growth path.

[9] We do not examine here switching between the regimes along the equilibrium path. One can show that the equilibrium trajectory cannot switch from the exogenous growth regime to the endogenous growth regime.

The drawback of the model is that it generates too high a speed of convergence to the steady state, irrespective of preference parameters. In order to solve this problem, S. Ortiguera and M. Santos (1997) introduced adjustment costs of new investment and obtained lower convergence rates relevant to empirical data. We, nonetheless, prefer a simple version of the model that easily extends to the global economy case and still remains analytically tractable.

3. THE GLOBAL ECONOMY

As was mentioned in the introduction, the model of growth with different regimes can explain obstacles to economic integration between advanced and less advanced countries. We extend the closed economy model to a world economy with N countries and free capital mobility. As in Lucas (1993, p. 254–255) and Barro and Sala-i-Martin (2001, p. 96–101), the global economy model contains only one final good, but international trade in goods can still take place. This mediates intertemporal exchange and allows for divergence of domestic investment and saving.

3.1. The global economy model

Households in country j are endowed initially with stocks of human capital h_{j0} and assets a_{j0}. Trade in the capital market is opened at an initial time moment and capital is reallocated instantaneously across countries according to the marginal return on production investment. Initial production capital k_{j0} located into country j, therefore, differs from initial stock of assets a_{j0} in this same country.

Countries have the same production technology, household preferences, population growth rate, and exogenous growth rate, but differ in the marginal productivity of knowledge creation g_{1j}, initial stocks h_{j0}, a_{j0} and initial size of population n_{j0}. They are ranked according to g_{1j}, so that $g_{11} \le g_{12} \le \ldots \le g_{1N}$. The problem of country j household is:

$$\max_{c_j, l_j, e_j, u_j, a_j, h_j} \int_0^{\infty} e^{-\delta t}[\ln c_j + \theta \ln l_j]dt, \tag{3.1}$$

$$\dot{a}_j = ra_j + wu_j h_j - (d+v)a_j - c_j, \tag{3.2}$$

$$\dot{h}_j / h_j = g_0 + g_{1j} e_j, \tag{3.3}$$

$$u_j + e_j + l_j = 1, \tag{3.4}$$

$$e_j \ge 0, \tag{3.5}$$

$j = 1, \ldots, N$. At any moment the global capital market equalizes total assets and production capital:

$$\sum_{j=1}^{N} n_j a_j = \sum_{j=1}^{N} n_j k_j . \tag{3.6}$$

The global real interest rate equalizes the marginal product of capital across countries, $r = \partial y_j / \partial k_j$. The wage rate is also equalized due to identity of technologies and linear homogeneity of production:

$$w = \partial y_j / \partial (u_j h_j) = (1 - \alpha)(r/\alpha)^{-\alpha/(1-\alpha)}.$$

The budget constraint (3.2) represents an accumulation of financial assets bringing net return $r - d - \nu$. The term $ra_j + wu_j h_j$ in (3.2) is GNP per capita.

Let

$$\varphi_j = n_j y_j / \sum_{k=1}^{N} n_k y_k ,$$

$x_j = c_j / a_j$ and $z_j = a_j / k_j$ denote country j 's share in world output, consumption rate and capital position. For the sake of simplicity we do not impose any explicit constraint on the sign of asset stocks held by households as this variable may take negative values along the transition path. In what follows, we impose constraints on the model parameters forbidding variables a_j, x_j, and z_j to be negative in the steady state.

Proposition 4. Given that N countries are growing endogenously, equilibrium dynamics of the global economy are defined by the interest rate r and a set of country-specific relative variables $\Omega_j = (x_j, l_j, z_j, \varphi_j, u_j, e_j)_{j = 1, \ldots, N}$ satisfying (3.3) and

$$\dot{x}_j / x_j = x_j - \beta r / z_j - \delta, \tag{3.7}$$

$$\dot{r} / r = \beta (R_j - g_{1j} l_j - r), \tag{3.8}$$

$$\dot{l}_j / l_j = g_{1j} u_j - \delta, \tag{3.9}$$

$$u_j = \beta r l_j / \theta x_j z_j, \tag{3.10}$$

$$l_j + u_j + e_j = 1, \tag{3.11}$$

$$\sum_{k=1}^{N} z_k \varphi_k = 1, \tag{3.12}$$

$j = 1, \ldots, N$ and $R_j = d + v + g_0 + g_{1j}$.

Equilibrium dynamic equations (3.7)–(3.11) are essentially similar to those for the closed economy. Equation (3.12), which follows from the market equilibrium condition (3.6) and capital allocation condition, $k_j = \alpha y_j/r$, specifies interconnections between national economies. According to (3.12), the average capital position weighted by shares of countries in global output is unity. These shares are determined on the basis of the knowledge accumulation equations (3.3).

The dynamic system for the global economy consists of $6 \times N + 1$ variables and $6 \times N + 1$ equations. Interest rate equation (3.8) is compatible for all countries if the following $N - 1$ conditions fulfill:

$$g_{1j}(1 - l_j) = g_{1k}(1 - l_k), \tag{3.13}$$

$j, k = 1, \ldots, N, j \neq k$. The number of equations is unchanged since N equations (3.8) transform to the unique interest rate equation.

Constraints (3.13) imply that leisure is adjusted in each country in such a way that interest rate changes are identical for all countries at any time. Leisure is a variable with law of motion (3.9) and is adjusted through variations in production intensity entering (3.9). Constraints (3.13) imply that $g_{1j}\dot{l}_j = g_{1k}\dot{l}_k$, which is consistent with (3.9) if

$$g_{1j}l_j(g_{1j}u_j - \delta) = g_{1k}l_k(g_{1k}u_k - \delta), \tag{3.14}$$

$j, k = 1, \ldots, N, j \neq k$. Production intensity depends on capital position z_j through (3.10). Therefore, adjustments of z_j in $N - 1$ countries ultimately ensure interest rate equalization. The capital position for a "residual" country is found from equilibrium condition (3.12).[10] Equations (3.13), (3.14), and (3.11) imply that the allocation of household time in $N - 1$ countries is determined by the allocation of time in the residual country. The global capital market preconditions, thereby, close interdependence of household behavior across countries.

The mechanism of interest rate equalisation through leisure adjustment is important for a realistic description of the global economy dynamics. Suppose again that $\theta = 0$, as is the case in the Lucas (1988) endogenous growth model. Then $l_j = 0$, and (3.8) becomes incompatible for countries with different g_{1j}. A straightforward extension of the Lucas model to the heterogeneous global economy implies a counterfactual outcome when all production capital concentrates initially in the most ad-

[10] In what follows we calculate z_j for the steady state.

vanced country N and interest rate is constant: $r = R_N$. There is no mechanism in this model eliminating the gap between r and R_j for all other countries.

Suppose now that some economies are open to the world capital market and grow exogenously.

Proposition 5. Equilibrium dynamics of the open economy under exogenous growth satisfy

$$\dot{x}_j / x_j = x_j - \beta r / z_j - \delta, \tag{3.15}$$

$$\dot{r} / r = \beta \frac{a + \rho + g_0 + u_j(\dot{x}_j / x_j + \dot{z}_j / z_j) - r}{1 + \beta u_j}, \tag{3.16}$$

$$u_j = \frac{\beta r}{\beta r + \theta x_j z_j}. \tag{3.17}$$

Interest rate equalization requires that the right hand sides of (3.16) and (3.8) coincide. This is provided from an adjustment of z_j and $\dot{z}_j / z_j$ at any moment. As we further demonstrate, the transition dynamic of this economy is explosive: in finite time, z_j tends to infinity and u_j becomes zero. In essence, production capital vanishes from the country that stops production activity at some moment of time.

3.2. Endogenous steady-state growth of the global economy

Suppose again that N economies are trading and growing endogenously, and consider the balanced growth path of the global economy ($r^{(e)}$, $\Omega^{(e)}$). It satisfies:

$$x_j = \beta\, r/z_j + \delta, \tag{3.18}$$

$$r = R_j - g_{1j}\, l_j, \tag{3.19}$$

$$u_j = \delta/g_{1j}, \tag{3.20}$$

$$\sum_{j=1}^{N} z_j \frac{n_{j0} h_{j0} / g_{1j}}{\sum_{k=1}^{N} n_{k0} h_{k0} / g_{1k}} = 1, \tag{3.21}$$

(3.10), (3.11), and (3.12). Equations (3.18)–(3.20) are similar to (2.10)–(2.12), determining the balanced growth path for the closed economy. Equation (3.21) is the equilibrium condition obtained from (3.12), (3.20), and the capital allocation condition:

$$y_j = (r/\alpha)^{-1/\beta}\, u_j h_j.$$

Notice that the autarky global equilibrium with $z_j = 1$ for all j is a solution of (3.21).

The interest rate equation is drawn from (3.10), (3.11), and (3.18)–(3.21) as

$$r^2 - (R_a - \delta\theta)r + \delta^2\theta/\beta = 0, \tag{3.22}$$

where

$$R_a = d+v + g_0+g_{1a},\ g_{1a} = \sum_{j=1}^{N} n_{j0}h_{j0} / (\sum_{k=1}^{N} n_{k0}h_{k0} / g_{1k})$$

is a harmonic average productivity of research. Equation (3.22) is analogous to (2.12) and has the similar properties. As above, we deal only with the higher root $r^{(e)} = r_2$. The steady state leisure is $l_j^{(e)} = (\theta\delta + z_j^{(e)}\omega)/g_{1j}$ where $\omega = \theta\delta^2/\beta r^{(e)}$, therefore, $g_{1j}(1 - l_j^{(e)}) = g_{1j} - \theta\delta - z_j^{(e)}\omega$. The term $g_{1j}(1 - l_j^{(e)})$ is equalized if the following equation fulfills for $z_j^{(e)}$:

$$z_j^{(e)} = 1 - (g_{1a} - g_{1j})/\omega, \tag{3.23}$$

$j = 1, \ldots, N$.[11] Hence, $z_j^{(e)}$ is increasing in g_{1j}, and $z_j^{(e)} < (>) 1$ for countries with $g_{1j} < (>)\ g_{1a}$.

We impose restrictions on the model parameters ensuring that x_j and z_j are non-negative in the steady state for all countries. These variables are positive in autarky while they may be negative for some countries in the open economy case. Such a long-run outcome means an exponential running of non-collateralized foreign debt, and should be ruled out as an implausible case of economic integration. Restriction on the sign of household assets, $z_j^{(e)} \geq 0$, implies that

$$g_{1j} \geq g_{1a} - \omega, \tag{3.24}$$

$j = 1, \ldots, N$.[12] This inequality holds if either the marginal productivity of knowledge creation in all countries is near the world average or the elasticity of leisure and the discount rate are quite high.

From (3.23), the steady-state endogenous growth rate is $g_{1j}e_j^{(e)} = g_{1a} - (1 + \theta)\delta - \omega$, $j = 1, \ldots, N$.[13] Thus, it is the same across countries (due

[11] Indeed, $g_{1j}(1 - l_j^{(e)}) = g_{1j-1}(1 - l_{j-1}^{(e)})$ implies that $z_j^{(e)} = z_{j-1}^{(e)} + (g_{1j} - g_{1j-1})/\omega$. Iterating terms yields $z_j^{(e)} = z_1^{(e)} + (g_{1j} - g_{11})/\omega$, $j = 2, \ldots, N$. Inserting $z_j^{(e)}$ into (3.21) we have: $z_1^{(e)} = 1 - (g_{1a} - g_{11})/\omega$, and this yields (3.23).

[12] This requirement is stronger than the standard no-Ponzi-game condition related to the budget constraint (3.2) and fulfilled for the balanced growth path with negative $z_j^{(e)}$.

[13] $g_{1j}e_j^{(e)} = g_{1j} - (1 + \theta)\delta - z_j^{(e)}\omega = g_{1j} - (1 + \theta)\delta - \omega + (g_{1a} - g_{1j}) = g_{1a} - (1 + \theta)\delta - \omega$.

to the interest rate equalization), and is positive if

$$g_{1a} > (1 + \theta)\delta + \omega. \tag{3.25}$$

This condition coincides with (2.17) obtained above for the closed economy. It requires that the average productivity of knowledge creation is high enough. Unlike the country-specific condition (3.24), (3.25) relates to the global economy.

Constraints (3.24) and (3.25) constitute conditions of economic integration via the global capital market. They constrain preference parameters δ and θ in the opposite way. Worldwide endogenous growth is positive if individuals are patient and inclined to creative activity. Contrarily, countries do not accumulate exponential debt if individuals are impatient and leisure loving. Unlike the closed economy case, consumer preferences ambiguously influence conditions of global growth.

3.3. Barriers to integration

Suppose that (3.24) holds for countries $j = N^*, \ldots, N$, and does not hold for $j = 1, \ldots, N^* - 1$ thus dividing the world into two groups of countries. Less advanced economies $1, \ldots, N^* - 1$ are unable to integrate on the endogenous basis without running exponential debt. They can remain in autarky and grow endogenously or exogenously depending on household preferences and their abilities to create knowledge. Another option is to integrate with the global capital market in a very specific pattern when nothing is produced domestically, no production capital is allocated at home, and human capital is not utilized. In such a regime the economy is growing exogenously since the intensity of knowledge creation is also zero and households devote all time to leisure.

This regime is associated with an economy of a *rentier* type in the sense that households become pure financial investors holding foreign assets. The steady state ratio of assets to capital is infinity, and, from (3.14), the steady state consumption rate equals δ. Per capita assets and consumption grow in the steady state at the worldwide rate $g^{(e)} = r^{(e)} - d - \rho$. Such a regime of growth is impossible in the closed economy. But it does exist, and may be welfare preferable to productive growth in the economy trading in the world capital market.

Advanced countries $\{N^*, \ldots, N\}$ can integrate without either an exponential accumulation of debt or a transforming to the rentier regime. Conditions of global long run equilibrium (3.24) and (3.25) are easily reformulated for the subset $\{N^*, \ldots, N\}$. The difference is that the average marginal productivity of knowledge creation relates just to this subset and depends on the threshold number N^* where $g_{1a} = g_{1a}(N^*)$ and $dg_{1a}(N^*)/dN^* \geq 0$. If, for instance, the discount rate is low the inequality (3.24) becomes very restrictive. From this it can be implied that N^* is near N, and $g_{1a}(N^*)$ is near g_{1N}. This means that only the most advanced countries can integrate if households are quite patient. Conversely, if either the elasticity of leisure or the discount rate is quite high, the condition of the worldwide endogenous growth (3.25) holds for j near N. Again, only the most advanced countries can integrate.

A numerical example illustrates this inference of the model. Let $\delta = 0.025$, $\theta = 2$, $\beta = 1.5$, $r^{(e)} = 0.085$, $N = 20$, and g_{1j} be distributed uniformly according to the rule: $g_{1j} = g_{1j-1} + 0.005$, $g_{11} = 0.055$, and $g_{1N} = 0.15$. Then $\omega = 0.0098$, $g_{1a}(N^*) \in (0.14, 0.145)$, $g_{1N^*} = 0.135$, and only four countries from twenty satisfy (3.24): $N - 3, \ldots, N$. Notice that the threshold level of g_{1j} sufficient for endogenous growth in autarky is $g_{15} = 0.085$, and that in this case 14 countries are able to grow endogenously.

Capital market imperfections are often viewed as the main obstacle to economic integration. Our model's barriers to integration stem from a structural heterogeneity of countries rather than exogenous borrowing constraints. If we imposed such a constraint, for example $z_j^{(e)} \geq z_{\min}$, condition (3.24) would imply a more stringent restriction on the variation of g_{1j} across countries. If, on the other hand, we did not restrict the sign of $z_j^{(e)}$ we would have to deal with the weaker condition that leisure is positive, thus, implying that $g_{1j} > g_{1a} - \omega - \delta\theta$. This restriction on the model parameters is qualitatively similar to (3.24).[14]

Essentially, the diversity of countries in g_{1j} is necessary for violation of (3.24). This condition is fulfilled if countries have the same $g_{1j} = g_1$ but differ in preference and technology parameters δ, θ or β. In this case, countries have different ω_j, and the steady-state capital positions are $z_j^{(e)} = \omega_j/\omega_a > 0$ where ω_a is the arithmetic average of ω_j.[15] Consequently, the diversity of countries in the engine of growth is a

[14] One could introduce exogenous minimal level of leisure $l_{\min}$ into the household utility function thereby imposing a stronger lower constraint on leisure: $l_j > l_{\min}$. In fact, (3.24) is equivalent to $x_j^{(e)} > 0$ or $l_j^{(e)} > \theta u_j^{(e)}$ since $x_j^{(e)} = \delta l_j^{(e)}/(l_j^{(e)} - \theta u_j^{(e)})$. Forbidding exponential debt expansion implies constraining the steady state leisure by a minimal value proportional to the intensity of production. This condition holds automatically for the closed economy, as seen from (2.12), (2.14), (2.15).

[15] Condition $g_1(1 - l_j^{(e)}) = g_1(1 - l_1^{(e)})$ implies $z_j^{(e)} = z_1^{(e)}\omega_j/\omega_1$. Inserting it into (3.21) yields: $z_1^{(e)} = \omega_1/\omega_a$ and, hence, $z_j^{(e)} = \omega_j/\omega_a$.

crucial barrier to economic integration rather than preference and technology.[16]

Structural heterogeneity of countries may appear in an uneven distribution of the initial total stocks of human capital $n_{j0}h_{j0}$ across countries. If this stock is concentrated in an advanced country N', then $g_{1a}(N^*)$ is near $g_{1N'}$, and N^* near N'. In such a case, uneven size distribution of countries is an obstacle to integration. Conversely, if the total stock of knowledge concentrates in the less advanced economies (due to population size), conditions of integration weaken.

Delaying trade liberalization reduces the chance for a less advanced country to integrate. Economies should grow at different rates before opening its capital market at time $t = 0$. If this is delayed indefinitely, the gap between initial stocks of human capital widens and the limit g_{1a} approaches g_{1N}. Thus, the longer the pre-integration period, the higher the weight of advanced countries in g_{1a}, and the larger the gap $g_{1a} - g_{1j}$ becomes for backward countries. As a result, the number of autarkic economies able to meet (3.24) tends to reduce in time.

3.4. Welfare comparison

An advanced economy with an ability to integrate has three options: to integrate and grow endogenously, to integrate and become a rentier, or to remain in autarky. Consider the choice between endogenous growth and a rentier regime for a small open economy unable to alter the world interest rate. We compare welfare for the balanced growth paths assuming, as above, the identity of initial asset stocks for the two aforementioned options.

The steady state growth rate is the same for both regimes with only the level effects mattering. The rentier regime is preferable if and only if the gain from higher leisure welfare-dominates the loss from lower consumption, *i.e.*, from (2.24),

$$(x_j^{(e)}/x_j^{(r)})(l_j^{(e)}/l_j^{(r)})^{\theta} \leq 1.$$

Here superscript (r) denotes the rentier regime. Consumption rate and leisure in this regime are $x_j^{(r)} = \delta$, $l_j^{(r)} = 1$. From (3.18) and (3.23) the

[16] This conclusion is true if one generalizes the engine of growth equation (3.3) to the case when capital is a factor of knowledge production, for example: $\dot{h}_j = g_0 h_j + g_{1j}(s_j k_j)^{\gamma}(e_j h_j)^{1-\gamma}$ where s_j is the share of capital allocated to this sector, and γ is a parameter.

steady-state consumption ratio is $x_j^{(e)}/x_j^{(r)} = (\theta\delta + \omega + \Delta g_{1j})/(\omega + \Delta g_{1j})$ where $\Delta g_{1j} = g_{1j} - g_{1a}$.[17] Similarly, the steady-state ratio of leisure is $l_j^{(e)}/l_j^{(r)} = (\theta\delta + \omega(1+\Delta g_{1j}/\omega))/g_{1j} = (\theta\delta + \omega + \Delta g_{1j})/g_{1j}$. As a result, the rentier regime becomes preferable if

$$(\theta\delta + \omega + \Delta g_{1j})^{1+\theta} \leq (\omega + \Delta g_{1j})\, g_{1j}^{\theta}\,. \tag{3.26}$$

For $\delta = 0$ and $\Delta g_{1j} > 0$ this is equivalent to $\Delta g_{1j} \leq g_{1j}$ or $g_{1a} \geq 0$. The rentier regime is, therefore, preferable for a large subset of advanced countries if δ is sufficiently small. This is due to the annulled growth effect and the level effect of higher leisure in the rentier regime dominating the level effect of lower consumption once households are assumed quite patient.

The numerical example in Table 2 illustrates the dependence between θ and the threshold value of δ below which the rentier regime is welfare-dominating (all other parameters are as above, $r^{(e)} = 0.085$, $g_{1j} = 0.1$, and $\Delta g_{1j} = 0$).

Table 2.

θ	1.2	1.5	1.7	2	2.2	2.5	2.7	3
Critical, $\delta \times 10^2$	0.60	1.17	1.33	1.43	1.45	1.44	1.42	1.39

The threshold discount rate for this example is above 0.01 for plausible values of the elasticity of leisure.

Consequently, if households are quite patient, the rentier regime is selected by a country able to integrate and grow endogenously. There is no positive connection between "thriftiness" and growth for an open economy. Excessively thrifty households will prefer financial investment to productive activity and knowledge creation.

3.5. Transitional dynamics of the global economy

We have shown above that if the elasticity of leisure or the discount rate is quite low, only countries with nearly the same marginal productivity of knowledge creation can integrate. From this we may analyze the transi-

[17] $x_j^{(e)}/x_j^{(r)} = (\beta r^{(e)}/z_j^{(e)} + \delta)/\delta = 1 + \beta r^{(e)}\omega/\delta\,(w + \Delta g_{1j}) = 1 + \delta\theta/(\omega + \Delta g_{1j}) =$
$= (\theta\delta + \omega + \Delta g_{1j})/(\omega + \Delta g_{1j})$.

tion dynamics of the global economy for the simplest case when g_{1j} is the same for all countries, $g_{1j} \equiv g_1$, and the national economies differ in their initial factor endowments a_{j0} and h_{j0}.[18] The difference in initial conditions is irrelevant for the balanced growth path ($r^{(e)}$, $\Omega^{(e)}$). Also, the steady state is the same for all countries as seen from (3.23) when implying that $z_j = 1$. Nevertheless, their transition dynamics may differ due to the diversity of initial endowments.

Interest rate equalization implies, in this case, identity of household time structure for all countries at any time. This is seen from conditions (3.13) and (3.14) implying that $l_j = l_k \equiv l$ and $u_j = u_k \equiv u$ for all j and k, as well as ensuring the identity of dynamic equations for the interest rate and leisure. From (3.11) $e_j = e_k \equiv e$ for all j and k, and at any time human capital grows at the same rate in all countries. Production capital and output also grow at the same rate since k_j is proportional to uh_j, and GDP growth rates converge instantaneously at the initial time. Equilibrium paths of countries differ only in consumption rates and capital positions.[19]

Denote the aggregate consumption rate as $x_a = \sum_{j=1}^{N} n_j c_j / \sum_{j=1}^{N} n_j a_j$. The global economy evolution can be described by aggregate variables x_a, r, l, and u, as the following proposition states.

Proposition 6. An aggregate equilibrium trajectory of the global economy in the endogenous growth regime satisfies the system

$$\dot{x}_a / x_a = x_a - \beta r - \delta, \tag{3.27}$$

$$\dot{r} / r = \beta(R - r - g_1 l), \tag{3.28}$$

$$\dot{l} / l = g_1 u - \delta, \tag{3.29}$$

$$u = \beta r l / \theta x_a. \tag{3.30}$$

This system is identical to (2.6)–(2.9) related to an autarky economy and satisfies Proposition 3 characterizing transitional dynamics. The aggregate global trajectory differs from the autarky trajectory only in initial

[18] Another reason is that the dynamic system for heterogeneous economies is hardly tractable analytically. In the case of 2 countries with different g_{1j} we obtain a highly non-linear system of dimension 5.

[19] Consumption growth rates are also identical along the transition path because the Euler equations are the same across countries.

conditions. The manifold of initial values satisfies the equation:

$$x_a = (H_0/A_0)(\beta/\theta)r\psi(r)l, \tag{3.31}$$

where $\psi(r) \equiv (r/\alpha)^{-1/(1-\alpha)} = k_j/uh_j$ is the input structure of production identical for all countries,

$$H = \sum n_j h_j,\ A = \sum n_j a_j$$

are the total stocks of human capital and assets, and H_0/A_0 is the initial knowledge-capital ratio of the global economy.

Consider an equilibrium trajectory for country j. The allocation of household time is determined by the global economy dynamics. Consumption rate and capital position satisfy country-specific equations (3.7) and

$$u = (\beta/\theta)rl/x_j z_j. \tag{3.32}$$

The capital allocation condition implies that $z_j = a_j/h_j u\psi(r)$. This and (3.32) yield a relationship for the consumption rate similar to (2.25):

$$x_j = (h_j/a_j)(\beta/\theta)r\psi(r)l. \tag{3.33}$$

The national economy path is defined by variables x_j, r, l, u, z_j which satisfy (3.7), (3.28), (3.29), (3.32), and (3.33).[20]

The phase diagram for the global and national economies is depicted in Fig. 3 portraying the phase space (x, r, l) where $x = x_a$ or x_j. All trajectories converge to the same stationary point G, but begin from different initial points.[21] The aggregate equilibrium trajectory begins from an initial point O_a, an intersection of the saddle path with the manifold of initial values M_a as defined by (3.31). This point determines the initial values r_0 and l_0. The national economy trajectory begins from an initial point $O_j = (x_{j0}, r_0, l_0)$ belonging to manifold M_j as defined by (3.33) and initial ratio h_{j0}/a_{j0}. Initial point O_j determines x_{j0} and z_{j0} for each national econ-

[20] Condition (3.33) holds along the transition path and determines at each instant of time a proportional cross-country relationship between consumption and wage since production intensity and leisure are the same across countries. Our model implies that this dependence is valid for the integrated global economy and invalid for the set of autarky economies that may differ at each instant in u, l and r.

[21] The disaggregated global economy is represented by a $3 + n$-dimensional dynamic system including (3.27)–(3.30) and n consumption rate equations $\dot{x}_j / x_j = (1 - \beta r / x_a)x_j - \delta$ obtained from (3.7), (3.30), (3.32). Linearized around the steady state, this system has a block-diagonal structure if the countries are small, and one can ignore the link between each x_j and x_a. Under the condition of proposition 3, the disaggregate global path is a saddle.

omy. Projections of country-specific trajectories on plane (l, r) coincide with the projection of the aggregate trajectory on this plane.

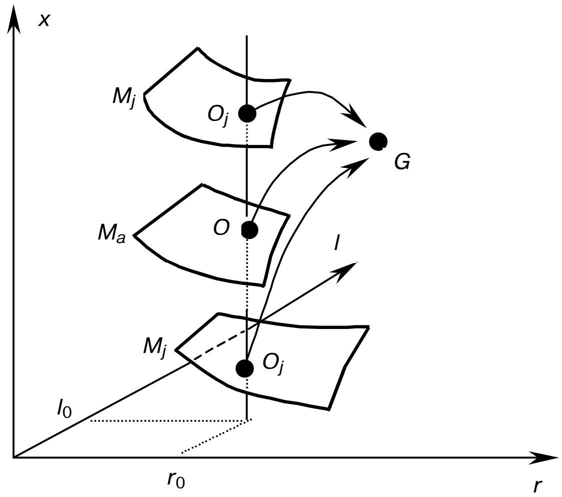

Fig. 3. Global equilibrium path.

Proposition 6 implies that the speed of convergence for the integrated global economy is the same as for the autarky economy. This result is consistent with empirical findings that groups of open economies converge slightly faster than do groups of more closed economies. Notably, the speed of convergence is finite and economies do not "jump" instantaneously to the steady state as predicted from direct extensions of closed economy models of growth. Barro *et al*. (1995) have demonstrated that convergence rate is finite for a small open economy facing both a fixed world interest rate and a borrowing constraint. In our model the interest rate is endogenous, and economies are not constrained by capital market imperfectness. Gradual convergence to the steady state is stipulated by an adjustment of household time and capital positions in different countries.

3.6. Transitional dynamics of the rentier economy

We mentioned above that an economy growing exogenously and trading in the world capital market transforms in the long run to the rentier economy with zero production. Consider the transition of a small open economy to this steady state. Suppose that the global economy is in the steady state with constant growth rate g and interest rate r. The growth rate differential is equal to $\Delta g = r - d - \rho - g_0$. Taking into account (3.17), we may represent the interest rate equation (3.16) as

$$\dot{\xi}_j / \xi_j = \Delta g (1 + (\theta / \beta r) \xi_j),$$

where $\xi_j = c_j/k_j$ is the consumption rate measured as a consumption-capital ratio. This equation is solved explicitly as

$$\xi_j = \xi_{j0} e^{\Delta g t} / [1 + (\theta / \beta r) \xi_{j0} (1 - e^{\Delta g t})],$$

where

$$\xi_{j0} = (\beta/\theta) r [(h_{j0}/a_{j0}) \psi(r) - 1]$$

is the initial consumption rate. This trajectory is explosive as ξ_j approaches infinity in finite time $T = ln(1 + \beta r/\theta\xi_{j0})/\Delta g = -\ln(l_{j0})/\Delta g$. The transition period is inversely related to initial leisure and the growth differential.[22] Table 3 demonstrates years of transition to the rentier regime for various values of growth rate differential and initial leisure ($l_{j0} = 0.4$ or 0.6).

Table 3.

Δg (%)	1.0	1.5	2.0	2.5	3.0	3.5
T ($l_{j0} = 0.4$)	92	61	46	37	31	26
T ($l_{j0} = 0.6$)	51	34	26	20	17	15

4. KNOWLEDGE SPILLOVERS AND INTEGRATION

So far we have ignored knowledge spillovers that constitute a factor of knowledge creation on the national level and facilitate economic integration. Lucas (1993) introduced positive spillover effects into the global economy model by assuming that the world stock of knowledge is a

[22] Initial consumption rate x_j and capital position z_j are selected from the locus of initial values to ensure that $x_j = \delta$ for $t \geq T$. Otherwise x_j would diverge from δ and tend to zero or infinity for $t \geq T$ because, given that $z_j = \infty$, equation (3.15) is globally unstable.

factor of knowledge production at home. In this case an economy with a stock of knowledge lower (higher) than the world average grows faster (slower) than the world economy. Not surprisingly, this assumption implies convergence of growth rates across countries. This prediction is intuitive, but it does not fit the empirical regularities (see Durlauf and Quah, 1999, p. 265–268).

We focus on another channel of knowledge spillovers materialized in foreign capital inflows, or, more precisely, in foreign direct investment (FDI). FDI-induced accumulation of knowledge is normally interpreted in the sense of technology and know-how transfers, labor force training within subsidiaries or parent companies of multinationals, copying of advanced technologies by domestic firms in a country receiving foreign investment. These effects increase productivity in a host country and are especially pronounced if investments are made by advanced economies into less advanced ones.[23] We will consider a small open economy and introduce investment-induced spillovers simply as a positive feedback between total production investment and an increase of per capita stock of knowledge. The model does not permit one to distinguish domestic and foreign production investment in the host economy and, therefore, FDI is treated as a part of total production investment.

Modify human capital equation (3.3) and assume that $g_0 = 0$:

$$\dot{h} = g_1 e h + g_2 \dot{k}.$$

The country subscript is omitted here and in what follows. The last term in this equation refers to the link between production investment and an increase of knowledge. Coefficient $g_2 \geq 0$ reflects the share of FDI in total investment and spillover effects of FDI. In percentage terms we have:

$$\dot{h} / h = g_1 e + g_2 u \psi(r) \dot{k} / k. \tag{4.1}$$

The product $g_2 u \psi(r) \equiv \varepsilon(u)$ indicates the elasticity of knowledge to production capital. It is increasing in production intensity in the host country and decreasing in the world interest rate.

[23] As R. Findlay (1978, p. 1) points out, "while the "book of blueprints" in some abstract sense may be open to the world as a whole, even if one may have to pay a stiff price to look at some of the pages, new technology generally requires demonstration in the context of the local environment before it can be transferred effectively, and it is in this connection that the overseas production of major world corporations with their headquarters in the advanced countries has such a vital part to play."

4.1. Endogenous growth

Suppose that at time $t = 0$ the economy enters the world capital market, given that the global economy is in the steady state regime with a constant growth rate g and interest rate r. The country's consumption starts to grow at $t = 0$ at constant rate $g = r - d - \rho$. Interest rate equation (3.8) transforms to

$$r = R - g_1 l + \varepsilon(u)\dot{k} / k .$$

Unlike the case with no external effects of investment, the economy can adjust to the world interest rate through an adjustment of time allocation and production capital. Household time allocation is no longer predetermined at each instant by interest rate equalization.

The growth of the national economy is expressed by a dynamic system:

$$\dot{z} / z = \dot{\xi} / \xi - \xi / z + \beta r / z + \delta, \tag{4.2}$$

$$\dot{\xi} / \xi = g + (R - r - g_1 l) / \varepsilon(u), \tag{4.3}$$

$$\dot{l} / l = g_1 u - \delta, \tag{4.4}$$

$$u = \beta\, rl / \theta\xi. \tag{4.5}$$

Here (4.2) is consumption rate equation (3.15) expressed in variables ξ and z, (4.3) is the interest rate equation and (4.4)–(4.5) are familiar time allocation equations. Subsystem (4.3)–(4.5) is an autonomous two-dimensional dynamic system with variables ξ and l. Equation (4.2) determines the initial conditions and transition dynamics considered below.

The steady state allocation of household time is

$$u^{(e)} = \delta / g_1, \qquad e^{(e)} = (1 - \varepsilon(u^{(e)}))g/g_1$$

since $R - r = g_1 - g - \delta$. The steady-state allocation of time does not depend on the elasticity of leisure since the economy grows at a constant worldwide rate. The intensity of knowledge creation in the steady state is positive if $\varepsilon^{(e)} < 1$ or

$$g_1 > g_2 \delta \psi, \tag{4.6}$$

where $\varepsilon^{(e)} \equiv \varepsilon(u^{(e)})$, $\psi \equiv \psi(r)$. In the opposite case domestic knowledge production is needless, $e^{(e)} = 0$, because production investment generates quite a rapid accumulation of knowledge.

The steady-state capital position and consumption rate satisfy[24]

$$z^{(e)} = \frac{\beta r(l^{(e)} - \theta u^{(e)})}{\theta \delta u^{(e)}}, \quad x^{(e)} = \frac{\delta l^{(e)}}{l^{(e)} - \theta u^{(e)}} \tag{4.7}$$

Both these ratios are non-negative if $l^{(e)} \geq \theta\, u^{(e)}$ or

$$g_1 > (1 - \varepsilon^{(e)})g + (1 + \theta)\delta. \tag{4.8}$$

If $g_2 = 0$, then $\varepsilon^{(e)} = 0$ and (4.8) transforms to (3.24) so that $g_1 \geq g_{1a} - \omega$. If $g_2 > 0$, spillover effects reduce (but not remove) barriers to integration for less advanced economies. Returning to our example of 20 countries with evenly distributed g_1 and now assuming that $\varepsilon^{(e)} = 0.5$ and $g = 0.03$, we can see that (4.8) is fulfilled for 12 countries. Recall that only 4 countries could meet the condition of integration (3.24) for that example. In fact, (4.8) is even weaker than the condition of autarkic endogenous growth (2.17) if $(1 - \varepsilon^{(e)})g < \omega$. In such a case trade in capital makes endogenous growth feasible for countries unable to grow in this regime in autarky.

4.2. Exogenous growth

Knowledge spillovers are the sole factor of growth in this case. Combining human capital equation (4.1) with the interest rate equation (3.16) yields $r = d + \rho + \varepsilon(u)\dot{k}/k + u\dot{\xi}/\xi$. Simple manipulations transform (3.15)–(3.17) into a dynamic system:

$$\dot{z}/z = \dot{\xi}/\xi - \xi/z + \beta r/z + \delta, \tag{4.9}$$

$$\dot{\xi}/\xi = g - \frac{g(\theta/\beta r)\xi}{g_2\psi - 1}, \tag{4.10}$$

where (4.9) is the consumption rate equation, (4.10) is the interest rate equation. The latter is independent from z and can be treated separately. It is globally stable if

$$g_2\psi > 1. \tag{4.11}$$

Otherwise, the economy is unstable and transforms into the rentier type in finite time.

The steady state fractions of time are $u^{(x)} = 1/g_2\psi$, $l^{(x)} = 1 - 1/g_2\psi$, and $\varepsilon(u^{(x)}) = 1$. The capital position and consumption rate in the steady state

[24] This is because $\xi^{(e)} = \beta r + \delta z^{(e)}$ and $\xi^{(e)} = \beta r l^{(e)}/\theta u^{(e)}$.

are expressed similarly to (4.7) and are positive if $l^{(x)} > \theta\, u^{(x)}$ or

$$g_2\psi > 1 + \theta, \tag{4.12}$$

which is sufficient for (4.11).

Constraints (4.6), (4.8), and (4.12) are depicted in Fig. 4. Zone 1 is the locus of parameters g_1 and g_2 where all constraints are fulfilled, and both regimes' long run growth is feasible. Zone 2 is a permissible domain for solely endogenous growth and zone 3 for exclusively exogenous growth. Zone 4 corresponds to the case where none of these regimes are feasible and the country has to choose between the autarky and rentier regime. For a broad range of g_2, endogenous growth is possible for a domain of g_1, which is visibly wider than the one for the model without FDI spillovers ($g_2 = 0$) plotted with a bold line.

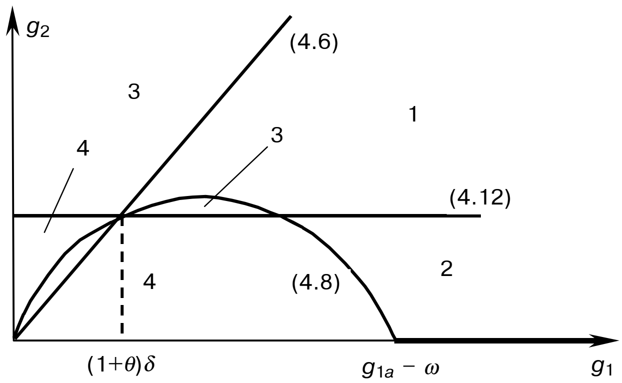

Fig. 4. Zones of g_1 and g_2.

4.3. Welfare comparison

Consider the choice between endogenous and exogenous growth for the steady state paths. The stationary growth rate is the same for both regimes so we focus on the level effects. From (2.24), exogenous growth is welfare-preferable if

$$(x^{(e)}/x^{(x)})(l^{(e)}/l^{(x)})^{\theta} \le 1. \tag{4.13}$$

The left-hand side of (4.13) is equal to

$$[(l^{(x)}-\theta u^{(x)})/(l^{(e)}-\theta u^{(e)})](l^{(e)}/l^{(x)})^{1+\theta}$$

and approaches

$$\frac{1-(1+\theta)/g_2\psi}{(1-1/g_2\psi)^{1+\theta}}(1-g)^{\theta} \tag{4.14}$$

if δ is low. The former factor of this expression is equal to 1 for $\theta = 0$ and below 1 for $\theta > 0$. Therefore, (4.13) is fulfilled for small δ. Exogenous growth is preferable since the growth rate is the same for both regimes and the level effect of leisure is dominating. We demonstrate again that patience does not favor endogenous growth of the open economy.

4.4. Patterns of transition growth

The equilibrium exogenous growth trajectory is globally stable, pending (4.11) holds. The endogenous growth trajectory is saddle-path stable for a wide domain of parameters, as the following proposition demonstrates.

Proposition 7. The endogenous growth trajectory is a saddle if

$$g_1 \geq g + \delta.^{25} \tag{4.15}$$

We distinguish two patterns of transition growth in each regime. The first pattern is characterized by a high initial capital inflow into the country and sluggish capital growth along the transition path. Production capital increases initially after opening the economy, but in transition to the steady state, it grows slower than the world economy and domestic consumption. We call such a pattern of development *booming* since the opening of domestic capital markets implies an immediate and quite rapid inflow of capital into the country. Under the second growth pattern household assets initially flow out from the country, but in transition its production capital grows more rapidly than the world economy and domestic consumption. We call this transition pattern *gradual* growth.

Consider the dependence between the choice of the growth pattern and the initial knowledge-asset ratio h_0/a_0 as denoted by σ_0. For convenience of exposition we will begin from the case of exogenous growth. The phase space of system (4.9)–(4.10) is depicted in Fig. 5, where horizontal line X shows the rest points of (4.10) and curve Z relates to the rest points of (4.9) (Z has a positive slope if (4.12) holds). Ray M portrays the locus of initial values satisfying the familiar equation:

$$\xi = (\beta r/\theta)[\sigma_0 \psi z - 1]. \tag{4.16}$$

[25] (4.15) is equivalent to $g_1 \geq g_{1a} - \delta\theta - \omega$, an essentially weaker constraint on g_1 than (3.24).

Initial consumption rate and capital position are the points of intersection of ray M and stable saddle path G_1 or G_2. Saddle path G_1 corresponds to the booming pattern of growth since ξ_0 is relatively low (below $\xi^{(x)}$) and ξ is increasing along the path. Saddle path G_2 is the trajectory of gradual growth since ξ_0 is relatively high (above $\xi^{(x)}$) and ξ is decreasing along the path. The equilibrium trajectory coincides with the balanced growth path when

$$\xi_0 = \xi^{(x)} = \beta r g_2 \psi^{(x)}/\theta = (\beta r/\theta)(g_2\psi - 1)$$

and, from (4.16), the initial knowledge-to-asset ratio is equal to

$$\sigma_0{}^{(x)} = 1/\psi u^{(x)} z^{(x)}.$$

Proposition 8. Exogenous transition growth is booming if $\sigma_0 > \sigma_0{}^{(x)}$, and gradual if $\sigma_0 < \sigma_0{}^{(x)}$.

This proposition is illustrated in Fig. 5 where the line of initial values M intersects either equilibrium path G_1 or G_2. According to Proposition 8, equilibrium growth is booming in the knowledge-redundant economy and gradual in the knowledge-scarce economy, thus establishing that an opening of trade eliminates an imbalance between knowledge and asset stocks. Moreover, if $z^{(x)} < 1$, then $z_0 < 1$ for path G_1 along with an overflow of capital at the initial moment. The knowledge-redundant economy becomes capital-redundant as a result of initial capital reallocation, but henceforth it accumulates capital

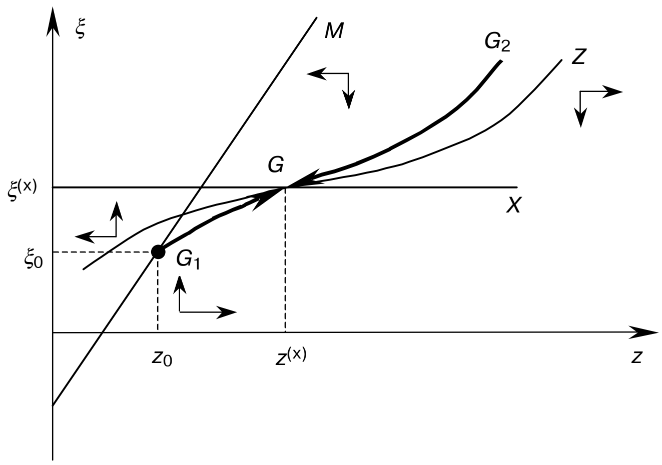

Fig. 5. Exogenous growth for the open economy.

at a rate below g. Initial capital outflow from the knowledge-scarce economy is also too intensive if $z^{(x)} > 1$ along with capital growth along transition path G_2 at a rate exceeding g.

We connect this result with the principle of comparative advantage since the threshold knowledge-to-asset ratio $\sigma_0{}^{(x)}$ is defined by the world interest rate. The pattern of transitional growth of the country is determined by a comparison of its initial endowment structure σ_0 with the threshold level related to the global economy.

One can show that the gradual pattern of transition growth welfare-dominates the booming pattern if the elasticity of leisure is sufficiently high. Indeed, expected household utility at time 0 is equal to

$$\int_0^\infty e^{-\delta t}(gt + \ln x_0 + \ln a_0)dt + \theta\int_0^\infty e^{-\delta t}\ln l dt =$$
$$= g/\delta^2 + [(\ln a_0) + (\ln x_0) + \theta E_0 \ln l]/\delta,$$

where

$$E_0 \ln l = \frac{\int_0^\infty (\ln l)e^{-\delta t}dt}{\int_0^\infty e^{-\delta t}dt}$$

is the expected time-weighted utility of leisure. Expected integral utility varies between growth patterns due to variations in both the initial consumption and expected utility of leisure. Initial consumption rate x_0 is higher for the booming growth pattern since, as seen from Fig. 5, the ratio $\xi_0/z_0 = x_0$ is higher for G_1. Expected utility of leisure is higher for the gradual growth pattern. Indeed, according to (3.17) leisure is linked to the consumption rate as: $l = \theta\xi/(\theta\xi + \beta r)$ with property l decreasing along transition path G_2 since ξ is decreasing. Hence, $E_0 ln l > ln l^{(x)}$ for G_2, while $E_0 ln l < ln l^{(x)}$ for G_1.

Expected utility of leisure enters integral utility with weight θ. As a result, the gradual pattern welfare dominates the booming pattern if leisure preference is quite strong and vice a versa. In other words, low initial knowledge-asset ratio is preferable for a country populated with leisure-loving households.

Two patterns of transition endogenous growth are demonstrated in Fig. 6 depicting the phase space of subsystem (4.3)–(4.5). Curve X is a locus of constant ξ whereas ray L is a locus of constant l. The locus of initial

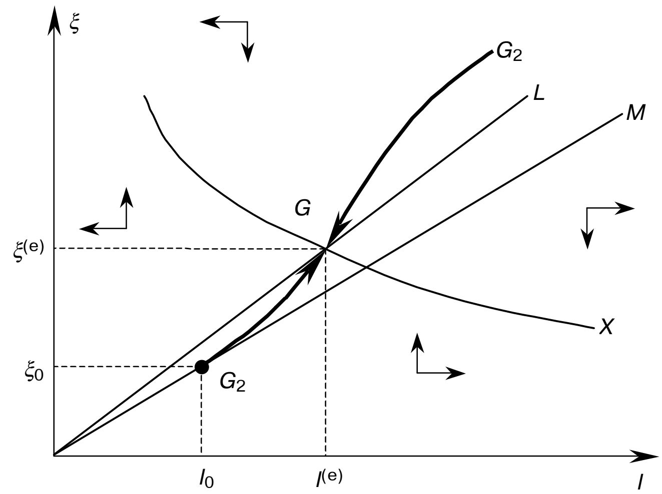

Fig. 6. Endogenous growth for the open economy.

values M is a ray defined by

$$\xi = (\beta r/\theta)\psi\sigma_0\, z_0 l. \tag{4.17}$$

There are two stable saddle paths corresponding to these patterns of growth. Consumption rate ξ and leisure are increasing along the first path G_1 and decreasing along the second path G_2. As above, the growth rate of production capital is below worldwide growth rate g for the first path and above g for the second path. Equilibrium trajectory is the balanced growth path if

$$\xi_0 = \xi^{(e)} = \beta r g_1 l^{(e)}/\theta\delta = (\beta r/\theta) l^{(e)}/u^{(e)}$$

or, from (4.17),

$$\sigma_0\, z_0 = 1/\psi u^{(e)}.$$

The choice of equilibrium path is determined by the location of ray M relative to ray L. If M has a lower slope than L, the booming path G_1 is selected. In the opposite case, the equilibrium trajectory is G_2 and transition growth is gradual. On the other hand, the choice of growth pattern is more complex than in the exogenous growth case since the slope of M depends on the product of σ_0 and z_0. The former is exogenous while the latter is determined simultaneously with ξ_0 and l_0. The resulting effect of variation in σ_0 seems ambiguous since, for instance, an increase of σ_0 stimulates additional initial inflow of production capital into the country and thus decreases z_0. This effect is sufficiently strong for realistic values of parameters as the following proposition implies.

Proposition 9. Let the convergence rate of the endogenous growth path $\mu^{(e)}$ satisfy

$$g \le -\mu^{(e)} \le g + \beta r/z^{(e)}. \tag{4.18}$$

Then growth near the steady state is booming for $\sigma_0 > \sigma_0{}^{(e)} \equiv 1/\psi u^{(e)}z^{(e)}$ *and gradual for* $\sigma_0 < \sigma_0{}^{(e)}$.

Convergence rate $\mu^{(e)}$ is the negative root of the characteristic equation for subsystem (4.3)–(4.5) derived in the proof of Proposition 7 (see Appendix A7). It satisfies the inequality $-\mu^{(e)} > g - \delta$, and, therefore, the left inequality in (4.18) is slightly restrictive for small δ. The right inequality may be restrictive for $\varepsilon^{(e)}$ near 1. This property is maintained for the above numerical example with $g_1 = 0.1$ if $\varepsilon^{(e)} = 0.5$ ($\mu^{(e)} = -0.126$, $z^{(e)} = 1.02$) and is not if $\varepsilon^{(e)} = 0.8$ ($\mu^{(e)} = -0.096$, $z^{(e)} = 1.94$).

Fig. 6 illustrates Proposition 9 and depicts the case $\sigma_0 > \sigma_0{}^{(e)}$. According to the proposition, $\sigma_0 z_0 < \sigma_0{}^{(e)}z^{(e)}$ and ray M intersects the booming path G_1. Consequently, growth is booming in the knowledge-redundant economy and gradual in the knowledge-scarce economy.

As in the exogenous growth regime, expected integral utility varies only with x_0 and $E_0 lnl$. Initial consumption rate $x_0 = \xi_0/z_0$ is higher for the booming growth pattern near the steady state. This is so since the projection of equilibrium trajectory on plane (ξ, z) is approximated near this state by a linear dependence of ξ on z with a positive slope and intercept (see equation (A13) in Appendix A9). The ratio ξ_0/z_0 has a direct relationship with z_0, so clearly this ratio becomes higher for G_1 when z_0 is lower than for G_2. The expected utility of leisure is higher for G_2 since leisure is higher on this path, as seen from Fig. 6. As above, the gradual pattern is welfare preferable for a high elasticity of leisure and vice versa.

Comparing threshold knowledge-asset ratios $\sigma_0^{(x)}$ and $\sigma_0^{(e)}$ for the endogenous and exogenous growth regimes, one can show that generally $\sigma_0^{(x)} > \sigma_0^{(e)}$.[26] This means that under exogenous growth the country must

[26] Indeed, $\sigma_0{}^{(x)} > \sigma_0{}^{(e)}$ is equivalent to $u^{(e)}z^{(e)} > u^{(x)}z^{(x)}$ or, from (4.7), to $l^{(e)} - \theta u^{(e)} > l^{(x)} - \theta u^{(x)}$. The latter inequality is rewritten as: $1 - (1-\varepsilon^{(e)})g - (1+\theta)\delta/g_1 > 1 - (1+\theta)/g_2\psi$ or $(1+\theta)(1/g_2\psi - \delta/g_1) > (1-\varepsilon^{(e)})g$. Since $\varepsilon^{(e)} = g_2\psi\delta/g_1$ we have that $\sigma_0{}^{(x)} > \sigma_0{}^{(e)}$ if and only if $(1+\theta)/g_2\psi > g$, or $(1+\theta)u^{(x)} > g$. This condition is fulfilled if the growth rate is below the intensity of production $u^{(x)}$.

initially have a higher minimal knowledge-asset ratio in order for the booming growth to begin. If $\sigma_0^{(x)} > \sigma_0 > \sigma_0^{(e)}$, the booming pattern of growth can occur only under endogenous growth. In a sense, a country with a moderate ratio of knowledge to assets narrows its opportunities to attract massive foreign investment at an initial stage of integration if it does not develop domestic knowledge production and relies solely on FDI as the main source of economic growth.

5. CONCLUDING REMARKS

The paper has examined stylized facts of global economic growth by analyzing two regimes of growth: endogenous, based on knowledge creation, versus exogenous, based on other sources. It was shown that some countries are unable to develop the knowledge-producing sector in autarky due to three types of obstacles: behavioral, technological, and institutional. High impatience and leisure preference constitute behavioral barriers to knowledge creation, while its low productivity reflects technological and institutional barriers.

We established that even if growth rates diverge for autarkic economies, they converge for countries trading in the world capital market (the club convergence). This, however, requires close similarity of economies in the club in terms of the engine of growth, otherwise, some of them run exponential debt. In our view, the condition on the model parameters forbidding such outcome is relevant to the pitfalls of globalization. If some countries in the real world follow this pattern of growth, they sooner or later default on debt. One can interpret the condition of no-exponential debt as forbidding trade in the global capital market for countries strongly exposed to the risk of default. In line with this interpretation, financial crises can be viewed as unsuccessful attempts of integration with the developed world by countries with low productivity of growth-generating sectors.

An introduction of knowledge spillovers embodied in FDI into the open economy model is important in two respects. First, it allows for transitional dynamics of a small open economy facing a constant world interest rate. Without the assumption of FDI-induced spillovers such an economy would be forced to jump instantaneously to the steady state. Second, it is an interesting extension of the basic model from the practical point of view. Many policy makers in transitional and developing economies trying to join the multilateral world economy appear to regard positive spillover effects of FDI as a crucial argument. We have shown that although these effects enhance opportunities for economic integration, they are not always a panacea against economic backwardness.

One should interpret the opening of a less developed economy as not only formal permission for residents to invest abroad and for non-residents to invest at home, but also as the removal of all institutional barriers restricting foreign investment. This requires dramatic improvements in the domestic legal system, corporate governance, taxation, *etc*. So understood, opening of home capital markets and initial reallocation of capital should be viewed as quite a long historical process, while in our model it takes only one instant, $t = 0$. Of course, one could change the "story" of the model a bit by assuming that trade liberalization and capital reallocation take a finite period of time $[-t_0, 0]$ preceding transitional growth.

Events occurring at the pre-transition period remain beyond the model description but still manage to determine the pattern of transitional growth. We have shown that growth is uneven over time and across countries: it may be booming or gradual in the pre-transition phase and, respectively, slow or fast in the transition phase. The booming growth pattern resembles the experience of some miraculous economies where an opening of trade caused a rapid increase of capital and output succeeded later by slowdowns of growth.[27] Initial knowledge-capital ratio in these economies is normally higher than in other developing countries. Of course, the scope of this analogy is very limited, but this is a consequence of the model's focus on trade in capital and neglect of trade in goods. It, henceforth, disregards export expansion, a typical feature of most post-war episodes of fast and long-lasting growth emphasized, for instance, by Lucas (1993) and Ventura (1997). The gradual growth pattern of our model is associated with the experience of less successful countries such as Latin American nations that were unable to escape capital outflows and slowdowns of growth after opening trade. The model predicts that if these economies do not close, they will be able to achieve higher growth at subsequent phases of integration.

The choice of the growth pattern in our model depends on the country's comparative advantage in growth-generating sectors. According to this inference, net outflow of capital from a country like Russia is explained (beyond the well known institutional problems) by its comparative disadvantage in knowledge creation. This is a consequence of the enormous per capita endowments of natural resources this country possesses. Undoubtedly, Russia has absolute advantages in some sectors of knowl-

[27] Such slowdowns and capital reversals are explained in Eicher and Turnovsky (1999) by capital market imperfections and debt subsidies.

edge production, but the size of its assets eliminates such advantages. This interpretation of the model conclusion helps to elucidate the nature of capital outflows from Russia at initial stages of its integration with the world economy, and the lack of foreign investment into Russia as compared to some other post-communist countries.

APPENDICES

A1. Proofs of Proposition 1

The Lagrangian for the problem (2.1)–(2.5) is

$$L = \ln c + \theta \ln(1-u-e) + \lambda_1(y - (d+v)k - c) + \lambda_2(g_0 + g_1 e)h + \chi e,$$

where λ_1 and λ_2 are co-state variables related to (2.2) and (2.3), respectively and χ is a dual variable related to (2.5). For the endogenous growth regime $\chi = 0$, and the first order conditions are

$$1/c = \lambda_1, \tag{A1}$$

$$\theta / l = \lambda_2 g_1 h, \tag{A2}$$

$$\theta / l = \lambda_1(1-\alpha)(k/uh)^{\alpha} h. \tag{A3}$$

The co-state equations are

$$\dot{\lambda}_1 = \delta\lambda_1 - (r - d - v)\lambda_1, \tag{A4}$$

$$\dot{\lambda}_2 = \delta\lambda_2 - (1-\alpha)(k/uh)^{\alpha} u\lambda_1 - (g_0 + g_1 e)\lambda_2. \tag{A5}$$

Combining (A2) and (A3) implies $(1-\alpha)(k/uh)^{\alpha} = g_1\lambda_2/\lambda_1$. Substituting this for (A5) yields

$$\dot{\lambda}_2 / \lambda_2 = \delta - g_1 u - \dot{h}/h. \tag{A6}$$

Taking log derivatives of (A2) yields $\dot{\lambda}_2 / \lambda_2 = -\dot{l}/l - \dot{h}/h$. Substituting this for (A6) implies (2.8).

Combining (A1) and (A4) yields

$$\dot{c}/c = r - d - \rho\ . \tag{A7}$$

Dividing (2.2) by k and subtracting (A7) from (2.2) yields

$$\dot{c}/c - \dot{k}/k = r - d - \rho - r/\alpha + d + v + x = x - \beta r - \delta.$$

This is equivalent to (2.6).

To derive (2.7) utilize (A7), (2.3), equation

$$(uh/k)^{1-\alpha} = r/\alpha \tag{A8}$$

and the log derivatives of (A3)

$$\dot{r}/r = \beta(\dot{l}/l + \dot{\lambda}_1/\lambda_1 + \dot{h}/h) = \beta(\dot{l}/l - \dot{c}/c + \dot{h}/h) =$$
$$\beta(g_1 u - \delta - r + d + \delta + g_0 + g_1 e) = \beta(d + v + g_0 + g_1(1-l) - r)$$

To derive the optimal rule (2.9) utilize (A1), rearrange (A3) to

$$\theta\, x/l = (1-\alpha)(k/uh)^{\alpha}(h/k),$$

and combine it with (A8).

A2. Proofs of Proposition 2

For the exogenous growth regime, $\chi \neq 0$ and $e = 0$, and the first order conditions are (A1), (A3) and $\theta/l = \lambda_2 g_1 h + \chi$. The co-state equations are (A4), (A5). Equation (2.19) is derived as (2.6) was. The optimal rule (2.21) is derived as (2.9) was. Differentiating (2.21) and rearranging terms yields

$$\dot{u}/u = l(\dot{r}/r - \dot{x}/x). \tag{A9}$$

Differentiating (A8) and utilizing (A9) implies

$$\dot{r}/r = (1-\alpha)(\dot{u}/u + \dot{h}/h - \dot{k}/k) =$$
$$= (1-\alpha)[l(\dot{r}/r - \dot{x}/x) + g_0 - r/\alpha + d + v + x] =$$
$$= (1-\alpha)[l\dot{r}/r + (1-l)\dot{x}/x + g_0 + d + \rho - r].$$

Therefore,

$$\dot{r}/r = \frac{(1-\alpha)(d + \rho + g_0 + u\dot{x}/x - r)}{1-(1-\alpha)l}.$$

This is equivalent to (2.20).

A3. Proofs of Proposition 3

The characteristic equation for system (2.6)–(2.9) linearized around the steady state ($x^{(e)}$, $r^{(e)}$, $l^{(e)}$) is

$$\begin{vmatrix} x^{(e)} - \mu & -\beta x^{(e)} & 0 \\ 0 & -\beta r^{(e)} - \mu & -\beta g_1 r^{(e)} \\ -\delta l^{(e)}/x^{(e)} & \delta l^{(e)}/r^{(e)} & \delta - \mu \end{vmatrix} = 0,$$

where μ is a characteristic root. This is a cubic polynomial

$$\mu^3 - 2\delta\mu^2 - B_1\mu - B_2 = 0,$$

where

$$B_1 = \delta\beta(r^{(e)} - g_1 l^{(e)}) + (\beta r^{(e)})^2 - \delta^2,$$

and

$$B_2 = \delta\beta(g_1 l^{(e)} x^{(e)} - \beta r g_1 l^{(e)} - r^{(e)} x^{(e)}) = \delta\beta\,(g_1 l^{(e)}\delta - r^{(e)} x^{(e)}).$$

This equation has one real negative root if and only if $B_2 < 0$, *i.e.*,

$$g_1 l^{(e)}\delta - r^{(e)} x^{(e)} < 0.$$

Utilizing (2.15) the left hand side of this inequality is equal to

$$x^{(e)}(g_1(l^{(e)} - \theta u^{(e)}) - r^{(e)}) = x^{(e)}(g_1(l^{(e)} - \theta u^{(e)}) - r^{(e)}) = x^{(e)}(\theta\delta^2/\beta r^{(e)} - r^{(e)}).$$

This is negative if and only if (2.27) holds.

Consider transition dynamics for the exogenous growth regime. Rearranging the right hand terms of (2.20) yields

$$\dot r / r = -\beta r + \beta \frac{r^{(x)}(\beta r + \theta x) + \beta r(x - \delta)}{\beta(1+\beta)r + \theta x}.$$

Differentiating (2.20) at the steady state $(x^{(x)}, r^{(x)})$ yields

$$\partial(\dot r / r)/\partial r = -\beta + \beta \frac{\beta(r^{(x)} + x - \delta)\theta x - \beta(1+\beta)r^{(x)}\theta x}{(\beta(1+\beta)r + \theta x)^2} =$$

$$= -\beta + \beta \frac{\beta(r^{(x)} + \beta r^{(x)})\theta x^{(x)} - \beta(1+\beta)r^{(x)}\theta x^{(x)}}{(\beta(1+\beta)r^{(x)} + \theta x^{(x)})^2} = -\beta,$$

$$\partial(\dot r / r)/\partial x = \frac{(\theta r^{(x)} + \beta r)\beta(1+\beta)r - \theta\beta r(r^{(x)} - \delta)}{(\beta(1+\beta)r + \theta x)^2} =$$

$$= \frac{\beta r^{(x)}(\theta\beta r^{(x)} + \beta r^{(x)} + \beta^2 r^{(x)} + \delta\theta)}{(\beta(1+\beta)r^{(x)} + \theta x^{(x)})^2} =$$

$$= \frac{\beta\theta r^{(x)} x^{(x)} + \beta^3(1+\beta)r^{(x)2}}{(\beta(1+\beta)r^{(x)} + \theta x^{(x)})^2} \equiv \upsilon < 1.$$

The characteristic equation for system (2.19)–(2.21) linearized throughout the steady state $(x^{(x)}, r^{(x)})$ is

$$\begin{vmatrix} x^{(x)} - \mu & -\beta x^{(x)} \\ \upsilon r^{(x)} & -\beta r^{(x)} - \mu \end{vmatrix} = 0.$$

This is a square equation $\mu^2 - \delta\mu + \beta x^{(x)} r^{(x)}(\upsilon - 1) = 0$ with one real negative root. Therefore, $(x^{(x)}, r^{(x)})$ is a saddle point.

A4. Proofs of Proposition 4

The Euler equation is (A7). Dividing (3.2) by a_j and subtracting it from (A7) yields

$$\dot{c}_j / c_j - \dot{a}_j / a_j = r - d - \rho - r - (1-\alpha) r / \alpha z_j + d + \nu + x_j = x_j - \beta r / z_j - \delta .$$

This is equivalent to (3.7). Equations (3.8), (3.9) and (3.10) are derived similarly to (2.7), (2.8) and (2.9). Equation (3.12) follows directly from (2.6).

A5. Proofs of Proposition 5

Equation (3.15) is derived similarly to (3.7); (3.16) and (3.17) are derived similarly to (2.20) and (2.21) after substituting $x_j z_j$ for x_j.

A6. Proofs of Proposition 6

Equations (3.28) and (3.29) follow from the identity of time allocation between countries. To derive (3.27) and (3.30), we begin by summing up (A7) and (3.2) across countries yielding, respectively,

$$\dot{C} / C = r - d - \rho , \tag{A10}$$

$$\dot{A} / A = r + w \sum_{j=1}^{N} u h_j n_j / A - (d + \nu) - C / A , \tag{A11}$$

where

$$C = \sum_{j=1}^{N} c_j n_j , \quad A = \sum_{j=1}^{N} a_j n_j ,$$

are total consumption and assets, correspondingly. Utilizing (A8) we yield

$$w \sum_{j=1}^{N} u h_j n_j / A = (1-\alpha)(r/\alpha)^{-\alpha/(1-\alpha)} (r/\alpha)^{1/(1-\alpha)} \sum_{j=1}^{N} k_j n_j / A = \beta \quad r .$$

Inserting this into (A11) and subtracting (A11) from (A10) implies (3.27). Summing (3.10) across countries yields (3.30) since $l_j \equiv l$.

A7. Proofs of Proposition 7

Characteristic equation for subsystem (4.3)–(4.4) linearized around the steady state is

$$\begin{vmatrix} -g - \mu & g / l^{(e)} - g_1 / \varepsilon^{(e)} \\ -\delta l^{(e)} / \xi^{(e)} & \delta - \mu \end{vmatrix} = 0 .$$

This is square polynomial

$$\mu^2 + (g - \delta)\mu - \delta(g - g/\xi^{(e)} + g_1 l^{(e)}/\varepsilon^{(e)}\xi^{(e)}) = 0.$$

A sufficient condition for one real negative root is $g_1 l^{(e)} > g\varepsilon^{(e)}$, or $g_1 - (1 - \varepsilon^{(e)})g - \delta > g\varepsilon^{(e)}$. This is equivalent to $g_1 > g + \delta$.

A8. Proofs of Proposition 8

We have to prove that the eigenvector of equilibrium trajectory in the steady state has a lower slope than M (see Fig. 5). The eigenvector corresponding to characteristic root $\mu = -g$ satisfies equation:

$$\begin{pmatrix} \delta + g & -1 - g\theta z^{(x)} / \beta r(g_2\psi - 1) \\ 0 & 0 \end{pmatrix} \begin{pmatrix} z - z^{(x)} \\ \xi - \xi^{(x)} \end{pmatrix} = 0 .$$

The slope of this eigenvector is equal to

$$\frac{\delta + g}{1 + g\theta z^{(x)} / \beta r(g_2\psi - 1)} = \frac{\delta + g}{1 + g(l^{(x)} - \theta u^{(x)}) / \delta l^{(x)}}$$

because

$$z^{(x)} = \frac{\beta r(l^{(x)} - \theta u^{(x)})}{\theta\delta u^{(x)}},$$

and $u^{(x)} = 1/g_2\psi$.

The slope of ray M intersecting the steady state is

$$(\beta r / \theta)\sigma_0^{(x)}\psi = \sigma_0^{(x)}\psi z^{(x)}\delta u^{(x)} / (l^{(x)} - \theta u^{(x)}) = \delta / (l^{(x)} - \theta u^{(x)}).$$

Therefore, the eigenvector has a slope lower than ray M if

$$\frac{(g + \delta)l^{(x)}(l^{(x)} - \theta u^{(x)})}{\delta l^{(x)} + (l^{(x)} - \theta u^{(x)})g} < 1.$$

This condition is satisfied since the product of the two numbers below 1 ($l^{(x)}$ and $l^{(x)} - \theta u^{(x)}$) is lower than their weighted average.

A9. Proofs of Proposition 9

The eigenvector of linearized system (4.2)–(4.4) corresponding to the negative characteristic root $\mu^{(e)}$ satisfies equations

$$\begin{pmatrix} \delta - \mu^{(e)} & -(1+gz^{(e)}/\xi^{(e)}) & z^{(e)}(g/l^{(e)} - g_1/\varepsilon^{(e)}) \\ 0 & -g-\mu^{(e)} & g/l^{(e)} - g_1/\varepsilon^{(e)} \\ 0 & -\delta l^{(e)}/\xi^{(e)} & \delta - \mu^{(e)} \end{pmatrix} \begin{pmatrix} z - z^{(e)} \\ \xi - \xi^{(e)} \\ l - l^{(e)} \end{pmatrix} = 0. \quad \text{(A12)}$$

Combining the first and second equation in (A12) yields

$$(\delta - \mu^{(e)})(z - z^{(e)}) = [(1 + gz^{(e)}/\xi^{(e)}) - z^{(e)}\,(g + \mu^{(e)})](\xi - \xi^{(e)})$$

or

$$C_1\xi = C_2 z + C_3, \quad \text{(A13)}$$

where

$$C_1 = (1 + gz^{(e)}/\xi^{(e)}) - z^{(e)}\,(g + \mu^{(e)}),$$
$$C_2 = \delta - \mu^{(e)},$$
$$C_3 = [(1 + gz^{(e)}/\xi^{(e)}) - z^{(e)}\,(g + \mu^{(e)})]\xi^{(e)} - (\delta - \mu^{(e)})z^{(e)}.$$

Coefficients C_1 and C_3 are positive due to (4.18) and since

$$\xi^{(e)} = \beta r + \delta z^{(e)}.$$

The third equation in (A12) is

$$l = C_4\xi + C_5, \quad \text{(A14)}$$

where

$$C_4 = \delta l^{(e)}/\xi^{(e)}(\delta - \mu^{(e)}) > 0,$$

$$C_5 = -\mu^{(e)}l^{(e)}/(\delta - \mu^{(e)}) > 0.$$

Initial point (z_0, ξ_0, l_0) satisfies (4.17) *i.e.*,

$$\xi_0 = D\sigma_0\, z_0 l_0,$$

where $D = (\beta r/\theta)\psi$. Substituting this for (A13) for $z = z_0$ and $\xi = \xi_0$ yields

$$C_1 D l_0 = C_2/\sigma_0 + C_3/\sigma_0\, z_0. \quad \text{(A15)}$$

Plugging (4.17) into (A14) for $l = l_0$ and $\xi = \xi_0$ and combining it with (A15) yields

$$\frac{C_1 C_5 D}{1 - C_4 D\sigma_0 z_0} - \frac{C_3}{\sigma_0 z_0} = \frac{C_2}{\sigma_0}.$$

The left-hand side of this equation is increasing in $\sigma_0 z_0$, which, therefore, inversely depends on σ_0. The product $\sigma_0 z_0$ determines the slope of line *M.* If $\sigma_0 > \sigma_0^{(e)}$, then $\sigma_0 z_0 < \sigma_0^{(e)} z_0^{(e)}$ and *M* intersects G_1. In this case, the initial point belongs to the booming transition path (see Fig. 6). If $\sigma_0 < \sigma_0^{(e)}$, *M* intersects G_2 and the initial point belongs to the gradual transition path.

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